

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

- 1 1. (Currently Amended) A linear method for performing head
2 motion estimation from facial feature data, the method comprising
3 the steps of:
4 obtaining a first facial image and detecting a head in said
5 first image;
6 detecting position of ~~not more than~~ only four points P of said
7 first facial image where $P = \{p_1, p_2, p_3, p_4\}$, and $p_k = (x_k, y_k)$;
8 obtaining a second facial image and detecting a head in said
9 second image;
10 detecting position of ~~not more than~~ only four points P' of
11 said ~~first~~ second facial image where $P' = \{p'_1, p'_2, p'_3, p'_4\}$ and $p'_i = (x'_i, y'_i)$;
12 and
13 determining the motion of the head represented by a rotation
14 matrix R and translation vector T using said points P and P' .

1 2. (Currently Amended) The linear method of claim 1, wherein
2 said only four points P of said first facial image and said only
3 four points P' of said second facial image include locations of
4 outer corners of each eye and mouth of each respective first and
5 second facial images.

1 3. (Original) The linear method of claim 1, wherein said
2 head motion estimation is governed according to:

3 $P'_i = RP_i + T$, where $R = \begin{bmatrix} r_1^T \\ r_2^T \\ r_3^T \end{bmatrix} = [r_{ij}]_{3 \times 3}$ and $T = [T_1 \ T_2 \ T_3]^T$ represent camera

4 rotation and translation respectively, said head pose estimation
5 being a specific instance of head motion estimation.

1 4. (Currently amended) A linear method for performing head
2 motion estimation from facial feature data, the method comprising
3 the steps of:

4 obtaining a first facial image and detecting a head in said
5 first image;

6 detecting position of four points P of said first facial image
7 where $P = \{P_1, P_2, P_3, P_4\}$, and $P_k = (x_k, y_k)$;

8 obtaining a second facial image and detecting a head in said
9 second image;

10 | detecting position of four points P' of said ~~first~~-second
 11 facial image where $P' = \{p'_1, p'_2, p'_3, p'_4\}$ and $p'_k = (x'_k, y'_k)$; and,

12 determining the motion of the head represented by a rotation
 13 matrix R and translation vector T using said points P and P' ,

14 wherein said head motion estimation is governed according to:

15 $P'_i = RP_i + T$, where $R = \begin{bmatrix} r_1^T \\ r_2^T \\ r_3^T \end{bmatrix} = [r_{ij}]_{3 \times 3}$ and $T = [T_1 \ T_2 \ T_3]^T$ represent camera

16 rotation and translation respectively, said head pose estimation
 17 being a specific instance of head motion estimation, and

18 wherein said head motion estimation is governed according to
 19 said rotation matrix R , said method further comprising the steps
 20 of:

21 determining rotation matrix R that maps points P_k to F_k for
 22 characterizing a head pose, said points F_1, F_2, F_3, F_4 representing three-
 23 dimensional (3-D) coordinates of the respective four points of a
 24 reference, frontal view of said facial image, and P_k is the three-
 25 dimensional (3-D) coordinates of an arbitrary point where
 26 $P_i = [X_i \ Y_i \ Z_i]^T$, said mapping governed according to the relation:

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$$\begin{aligned} R(P_2 - P_1) &\propto [1 \ 0 \ 0]^T \\ R(P_3 - P_1) &\propto [0 \ 1 \ 0]^T \end{aligned}$$

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30 wherein P_5 and P_6 are midpoints of respective line segments
 31 connecting points P_1P_2 and P_3P_4 and, line segment connecting points
 32 P_1P_2 is orthogonal to a line segment connecting points P_5P_6 , and
 33 \propto indicates a proportionality factor.

1 5. (Original) The linear method of claim 4, wherein
 2 components r_1 , r_2 and r_3 are computed as:

$$\begin{aligned} r_2^T(P_2 - P_1) &= 0 \\ r_3^T(P_2 - P_1) &= 0 \\ r_1^T(P_6 - P_5) &= 0 \\ r_3^T(P_6 - P_5) &= 0 \end{aligned}$$

1 6. (Original) The linear method of claim 5, wherein
 2 components r_1 , r_2 and r_3 are computed as:

$$\begin{aligned} r_3 &= (P_6 - P_5) \times (P_2 - P_1), \\ r_2 &= r_3 \times (P_2 - P_1) \\ r_1 &= r_2 \times r_3 \end{aligned}$$

1 7. (Original) The linear method of claim 4, wherein

$$\begin{bmatrix} P_1^T & 0^T & 0^T & 1 & 0 & 0 \\ 0^T & P_2^T & 0^T & 0 & 1 & 0 \\ 0^T & 0^T & P_5^T & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ T \end{bmatrix} = P'$$

3 each point pair yielding 3 equations, whereby at least four
4 point pairs are necessary to linearly solve for said rotation and
5 translation.

1 8. (Original) The linear method of claim 7, further
2 comprising the step of: decomposing said rotation matrix R using
3 Singular Value Decomposition (SVD) to obtain a form $R = USV^T$.

1 9. (Original) The linear method of claim 7, further
2 comprising the step of computing a new rotation matrix according to
3 $R = UV^T$.

1 10. (Original) A linear method for performing head motion
2 estimation from facial feature data, the method comprising the
3 steps of:
4 obtaining image position of four points P_k of a facial image;
5 determining a rotation matrix R that maps points P_k to F_k for
6 characterizing a head pose, said points F_1, F_2, F_3, F_4 representing
7 three-dimensional (3-D) coordinates of the respective four points
8 of a reference, frontal view of said facial image, and P_k is the

9 three-dimensional (3-D) coordinates of an arbitrary point where
 10 $P_i = [X_i \ Y_i \ Z_i]^T$, said mapping governed according to the relation:

11

$$R(P_2 - P_1) \propto [1 \ 0 \ 0]^T$$

12

$$R(P_6 - P_5) \propto [0 \ 1 \ 0]^T$$

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14 wherein P_5 and P_6 are midpoints of respective line segments
 15 connecting points P_1P_2 and P_3P_4 and, line segment connecting points
 16 P_1P_2 is orthogonal to a line segment connecting points P_5P_6 , and
 17 \propto indicates a proportionality factor.

1 11. (Original) The linear method of claim 10, wherein
 2 components r_1 , r_2 and r_3 are computed as:

$$r_2^T (P_2 - P_1) = 0$$

$$r_3^T (P_2 - P_1) = 0$$

3

$$r_1^T (P_6 - P_5) = 0$$

$$r_3^T (P_6 - P_5) = 0$$

1 12. (Original) The linear method of claim 11, wherein
 2 components r_1 , r_2 and r_3 are computed as:

$$3 \quad r_3 = (P_6 - P_5) \times (P_2 - P_1),$$

$$r_2 = r_3 \times (P_2 - P_1)$$

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$$r_1 = r_2 \times r_3$$

1 13. (Original) The linear method of claim 12, wherein a
2 motion of head points is represented according to $P'_i = RP_i + T$

$$R = \begin{bmatrix} r_1^T \\ r_2^T \\ r_3^T \end{bmatrix} = [r_{ij}]_{3 \times 3}$$

3 where $T = [T_1 \ T_2 \ T_3]^T$ represents image rotation, $T = [T_1 \ T_2 \ T_3]^T$

4 represents translation, and P'_i denotes a 3-D image position of four
5 points P_k of another facial image

1 14. (Original) The linear method of claim 13, wherein

$$2 \quad \begin{bmatrix} P_i^T & 0^T & 0^T & 1 & 0 & 0 \\ 0^T & P_i^T & 0^T & 0 & 1 & 0 \\ 0^T & 0^T & P_i^T & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ T \end{bmatrix} = P'_i,$$

3 each point pair yielding 3 equations, whereby at least four
4 point pairs are necessary to linearly solve for said rotation and
5 translation.

1 15. (Original) The linear method of claim 14, further
2 comprising the step of: decomposing said rotation matrix R using
3 Singular Value Decomposition (SVD) to obtain a form $R = USV^T$.

1 16. (Original) The linear method of claim 15, further
2 comprising the step of computing a new rotation matrix according to
3 $R = UV^T$.

1 17. (Currently Amended) A program storage device readable by
2 machine, tangible embodying a program of instructions executable by
3 the machine to perform method steps for performing head motion
4 estimation from facial feature data, the method comprising the
5 steps of:
6 obtaining a first facial image and detecting a head in said
7 first image;
8 detecting position of ~~not more than~~ only four points P of said
9 first facial image where $P = \{p_1, p_2, p_3, p_4\}$, and $p_k = (x_k, y_k)$;
10 obtaining a second facial image and detecting a head in said
11 second image;
12 detecting position of ~~not more than~~ only four points P' of
13 said ~~first~~ second facial image where $P' = \{p'_1, p'_2, p'_3, p'_4\}$ and $p'_k = (x'_k, y'_k)$;
14 and,
15 determining the motion of the head represented by a rotation
16 matrix R and translation vector T using said points P and P' .

1 18. (Currently amended) The program storage device readable
2 | by machine as claimed in claim 17, wherein said only four points P
3 | of said first facial image and only four points P' of said second
4 | facial image include locations of outer corners of each eye and
5 | mouth of each respective first and second facial image.

1 19. (Original) The program storage device readable by
2 machine as claimed in claim 17, wherein said head motion estimation
3 is governed according to:

4 $P'_i = RP_i + T,$ where $R = \begin{bmatrix} r_1^T \\ r_2^T \\ r_3^T \end{bmatrix} = [r_{ij}]_{3 \times 3}$ and $T = [T_1 \ T_2 \ T_3]^T$ represent
5 camera rotation and translation respectively, said head pose
6 estimation being a specific instance of head motion estimation.

1 20. (Previously presented) A program storage device
2 readable by machine, tangible embodying a program of instructions
3 executable by the machine to perform method steps for performing
4 head motion estimation from facial feature data, the method
5 comprising the steps of:
6 obtaining a first facial image and detecting a head in said
7 first image;

8 detecting position of four points P of said first facial image
 9 where $P = \{P_1, P_2, P_3, P_4\}$, and $P_k = (x_k, y_k)$;
 10 obtaining a second facial image and detecting a head in said
 11 second image;
 12 detecting position of four points P' of said ~~first~~second
 13 facial image where $P' = \{P'_1, P'_2, P'_3, P'_4\}$ and $P'_k = (x'_k, y'_k)$; and
 14 determining the motion of the head represented by a rotation
 15 matrix R and translation vector T using said points P and P' ,
 16 wherein said head motion estimation is governed according to:

$$R = \begin{bmatrix} r_1^T \\ r_2^T \\ r_3^T \end{bmatrix} = [r_{ij}]_{3 \times 3}$$

17 $P'_i = RP_i + T$, where and $T = [T_1 \ T_2 \ T_3]^T$ represent
 18 camera rotation and translation respectively, said head pose
 19 estimation being a specific instance of head motion estimation, and
 20 wherein said head pose estimation is governed according to
 21 said rotation matrix R , said method further comprising the steps
 22 of:

23 determining rotation matrix R that maps points P_k to F_k for
 24 characterizing a head pose, said points F_1, F_2, F_3, F_4 representing three-
 25 dimensional (3-D) coordinates of the respective four points of a
 26 reference, frontal view of said facial image, and P_k is the three-

27 dimensional (3-D) coordinates of an arbitrary point where
 28 $P_i = [X_i, Y_i, Z_i]^T$, said mapping governed according to the relation:

29

$$\begin{aligned} R(P_2 - P_1) &\propto [1 \ 0 \ 0]^T \\ R(P_6 - P_5) &\propto [0 \ 1 \ 0]^T \end{aligned}$$

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32 wherein P_5 and P_6 are midpoints of respective line segments
 33 connecting points P_1P_2 and P_3P_4 and, line segment connecting points
 34 P_1P_2 is orthogonal to a line segment connecting points P_5P_6 , and
 35 \propto indicates a proportionality factor.

1 21. (Previously presented) The program storage device
 2 readable by machine as claimed in claim 20, wherein components r_1 ,
 3 r_2 and r_3 are computed as:

$$\begin{aligned} r_2^T (P_2 - P_1) &= 0 \\ r_3^T (P_2 - P_1) &= 0 \\ r_1^T (P_6 - P_5) &= 0 \\ 4 \quad r_3^T (P_6 - P_5) &= 0 \end{aligned}$$

1 22. (Previously presented) The program storage device
 2 readable by machine as claimed in claim 20, wherein components r_1 ,
 3 r_2 and r_3 are computed as:

$$r_3 = (P_6 - P_5) \times (P_2 - P_1),$$

$$r_2 = r_3 \times (P_2 - P_1)$$

$$r_1 = r_2 \times r_3$$

23. (Previously presented) The program storage device
readable by machine as claimed in claim 20, wherein

$$\begin{bmatrix} P_i^T & 0^T & 0^T & 1 & 0 & 0 \\ 0^T & P_i^T & 0^T & 0 & 1 & 0 \\ 0^T & 0^T & P_i^T & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ T \end{bmatrix} = P_i'$$

each point pair yielding 3 equations, whereby at least four
point pairs are necessary to linearly solve for said rotation and
translation.

24. (Previously presented) The program storage device
readable by machine as claimed in claim 23, further comprising the
steps of decomposing said rotation matrix R using Singular Value
Decomposition (SVD) to obtain a form $R = USV^T$.

25. (Previously presented) The program storage device
readable by machine as claimed in claim 23, further comprising the
steps of computing a new rotation matrix according to $R = UV^T$.